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Swedish University of Agricultural Sciences
Department of Animal Nutrition and Management

Examensarbete 269

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Abstract

Salt (NaCl) is an essential element in many plants and in the diets of humans and animals. Salt is even a preservative, protecting against spoilage and coincidentally maintaining life. In most places around the world, pasture and grain are deficient in both sodium (Na^+) and chloride (Cl^-) and animals have to be fed supplemental salt to satisfy their sodium requirement. Deficiency in chloride is not usual; therefore, the focus of this work is on sodium alone.

Sodium contributes to many processes in the body: for example, the maintenance of body temperature, chemical transport and nerve function. Sodium, together with potassium (K^+) and chloride, is one of the most important ions for the body regulates pH and osmotic pressure. Deficiency in sodium is not always easy to detect but can lead to decreased appetite, weight gain, fertility, milk production and even weight loss. Excess of sodium is generally not a big problem as long as the animals have free access to water of good quality.

The sodium requirements for cattle, small ruminants and horses were calculated from National Research Council (NRC) and Swedish recommendations. Their expected sodium intakes from food were estimated to see if the animals were capable of compensating for the sodium deficit by unlimited access to a saltlick. These calculations showed insufficient intake of sodium in most of the cases and that access to saltlicks could not always fulfil animal needs.

A cow (650 kg) producing on average 31 kg energy-corrected milk has a sodium deficiency of between 3.3 and 17.7 g/day, depending on the feeding plan. A sheep 6 weeks before lambing lacks 1.7 g Na/day according to Swedish recommendations, although according to the NRC its sodium requirements are fulfilled. A lactating goat lacks 5.3 g Na/day according to Swedish recommendations and 1.8 g Na/day according to the NRC. For small ruminants, the recommendations for maintenance differ a lot between Swedish and NRC recommendations. The sodium requirements for a horse in normal training are almost fulfilled according to both Swedish and NRC recommendations. A horse in hard training, with big mineral losses in the sweat, lacks 14.3 g Na/day according to the NRC and 19.5 g Na/day according to Swedish recommendations.

This study points out that supplemental salt is needed and that more studies are need to investigate the actual intake by saltlick.

Introduction

Salt (NaCl) is an essential element in many plants and in the diet of humans and animals (Salt institute, 2007). It prevents dehydration, stimulates digestion and improves the body's ability to absorb minerals and trace elements. Salt deficiency can lead to decreased appetite, reduced weight gain and even weight loss. Fertility and production may also decrease. Salt is an important element of life.

History

Because of its ability to prevent spoilage and coincidentally maintain life, salt has been associated with long life and durability (Kurlansky, 2002). From old scripts you can see that salt has always been an important product. The Chinese script "Png-tzao-kan-mu" was written about 4,700 years ago (2,700 years B.C.) and is one of the earliest known writings (Salt institute, 2007). In it, one can read about more than 40 types of salt. It also describes methods of extracting and processing salt, similar to methods still used today. Salt has also played an important role in the rituals of many religions. The ancient Egyptians used salt to mummify their dead. Within Judaism salt is the symbol for perpetuity. Every Friday night they dip Sabbath bread in salt; the bread is then preserved and becomes a symbol for the agreement between God and his people. Both Muslims and the Jews seal an agreement with salt because it is unchangeable (Kurlansky, 2002).

Salt has also been a key factor in social and political development. A friend to Sigmund Freud called Ernest Jones, who was one of the leading craftsmen when psychoanalysis was introduced, claimed that salt is often associated with fertility (Kurlansky, 2002). He based this statement on the fact that the Romans called a man in love, *salax* (salted). *Salax* is also the origin of the English word salacious.

In the 1920s, Diamond Crystal Salt Company of Saint Clair in Michigan published a folder with "One Hundred and One Uses for Diamond Crystal Salt" (Kurlansky, 2002). One example from the folder is that salt cures bad digestion. In fact there are many more than 101 ways to use salt: the modern salt industry talks about 14 000 ways.

In the early middle ages, farmers in North Europe protected their grain against ergot (*Claviceps purpurea*), a fungi that poisons both people and animals, by placing the grain in salt water (Kurlansky, 2002). It is established that the agricultural civilisations in North America during the 17^{th} and 18^{th} century extracted and used salt but there is no evidence that the hunter-gatherer civilisations did so. How humans found out that salt must be added to the crops is an unanswered question but the salty taste was probably detected when crops were irrigated with seawater. In contrast to a ruminant's salt appetite, a human's salt appetite seems to be conditioned. Humans cannot feel hunger for salt as can other animals (Morris, 1980). One of the first methods to find salt was to follow animal tracks, because animals instinctively establish trails leading to natural salt sources.

In the past, farmers salted the hay during harvesting before they stored it in the barn to lower the moisture content. Subsequently, the animals that were fed the hay got sufficient salt. In contemporary harvest and storage systems, salt are not necessary for preservation and consequently saltlicks had to be introduced (Pehrson, 1983).

Now that salt is so cheap we have forgotten that, up until 100 years ago, it was one of the most coveted commercial goods and has even served as currency at many times and places (Kurlansky, 2002; Salt institute, 2007).

Function of sodium chloride (NaCl) in animal physiology

Animals are often fed sodium (Na^+) and chlorine (Cl^-) in the form of common salt (NaCl), either in saltlicks, as salt granules or mixed with the feed. Salt consists of 39 % sodium and 61 % chlorine (Holum, 1998; NRC, 2007b). Sodium and chlorine have a close ionic relationship and are often mentioned together as the compound salt. Even if sodium and chlorine are very dangerous as elements - sodium (Na) is a shiny metal that reacts explosively with both oxygen and moisture in the air, while chlorine (Cl_2) is a poisonous gas - both ions are essential for life (Holum, 1998).

Its availability, cheapness, palatability and relativity low toxicity have promoted a generous use of salt. This has led to the establishment of minimum recommendations alone for animals (Underwood, 1981). Moreover, salt is not easily found in all locations around the world. In tropical countries, where the need for salt is greatest, salt availability is unsatisfactory and prices are often high.

The function of Sodium (Na^+)

Sodium (Na^+) is the principal cation in interstitial fluid and has many functions in the body. It is an accessory in many transport systems, such as the absorption of chlorine, amino acids, glucose and water (ARC, 1980; NRC, 1996; NRC, 2007b). Sodium is also involved in important transport systems for neuromuscular activity, nerve function and maintenance of body temperature. Together with potassium (K^+) and chloride (Cl^-), sodium is one of the most important ions for the body to regulate pH and osmotic pressure.

Most of the sodium in the body is found in body fluids and in bone (Underwood, 1981). The normal sodium concentration in blood plasma is between 3.2-3.5 mg/l. This concentration is not affected by sodium deficiency; therefore, it is not possible to test blood plasma to see if an animal has a sodium deficiency. Only when an animal has a dire shortage does the sodium concentration of blood plasma decline (Underwood, 1981). Rather, as a result of insufficient sodium intake, the volume of an animal's blood plasma and interstitial fluid will decrease (Michell, 1989). The body has a great ability to conserve sodium with help from the kidney and absorption from both the large and small intestine (NRC, 2001). The responsible hormone is aldosterone, which is excreted from the adrenal cortex when sodium levels decrease in the blood (Holum, 1998; NRC, 1996). There is a reduction in urinary and faecal sodium of an animal according to sodium re-absorption against a concentration gradient, from the urine in the kidney and from the faeces in the intestine into the blood (Underwood, 1981; NRC, 1996). Sodium leaves the body mainly through urine, sweat and milk.

The function of Chloride (Cl^-)

Chloride is the body's principle anion and is involved in the absorption of amino acids and minerals, digestion of proteins, regulation of osmotic pressure and maintenance of the acid-base balance (NRC, 1996; Underwood, 1981). When proteins are digested, chlorine contributes by activating the catabolic enzyme amylase and forming hydrochloric acid, which is one of the substances in the gastric juice (NRC, 1996). It is also involved in the transport of oxygen (O_2) and carbon dioxide (CO_2).

Most of the chlorine in the body is found in the interstitial fluids as chloride and the total concentration is approximately 0.10-0.11 % (Puls, 1994). Animals excrete more than 90 % of the chloride in urine. If there is high chloride concentration in the plasma, it is probably caused by dehydration or metabolic acidosis (NRC, 2007b).

The absorption rate for chloride is 100 % which differs from sodium with absorption of approximately 80-90 % (NRC, 2007a). Both deficiency and excess of chloride is unusual. Therefore this project is mainly focused on sodium.

Deficiency

Chloride deficiency is unusual in animals and has never been shown among small ruminants (NRC, 2007b; Underwood, 1981). However, there is a distinct correlation between chloride deficiency and metabolic alkalosis in horses, as a result of the compensatory increase in bicarbonate (NRC, 2007a). Due to limited references about chloride, this part mainly concerns sodium.

When sodium losses and sodium requirements for growth, pregnancy, lactation and work exceed intake, sodium deficiency can occur (Michell 1985). The herbivore diet is low in sodium and there is a high risk for negative sodium balance if losses are increased (Jansson, 1999). The signs of sodium deficiency in animals are not clear. Often, they show poor appetite, decreased weight gain and reduced milk production, all of which can indicate many other things, for example other nutrient deficiencies or a variety of diseases (NRC, 1996; Underwood, 1981). The first sign of sodium deficiency among cattle is the expression of appetite for salt through licking wood, soil or sweat from other animals (Underwood, 1981). Animals that have little or no access to salt become sodium deficient and show fervent appetite for sodium (Robbins, 1993; Denton and Sabine, 1961). They develop something that is called perverse appetite, meaning that they start to consume soil, trees, stones and even faeces and urine. They also seek out regions rich in sodium, or saltlicks (Staaland and White, 2001). Thereafter, appetite declines, their coat gets rough and milk yield decreases (NRC, 1996).

The concentration of sodium in blood plasma does not decline when an animal experiences sodium deficiency, until it is extreme (Underwood, 1981). Therefore, blood plasma is not a good reference to measure an animal's sodium status. Likewise, urine and faecal sodium excretions are poor references because they are very quickly reduced when the body needs to conserve sodium (Bott *et al*., 1964). McSweeney *et al*. (1988) performed tests on sheep and goats to diagnose the sodium status in small ruminants. Their results indicate that aldosterone is the best indicator of sodium status. Sodium balance was poorly correlated to the sodium status of animals, maybe because of inaccuracies in measuring sodium intake and output. Instead, one can use the Na:K ratio in saliva, which is normally around 20:1 in cattle. Saliva usually contains 3.22-4.14 g Na/l and 0.27 g K/l. In response to aldosterone secretion from the adrenal glands and increased sensitivity of the parotid gland to the hormone, potassium concentrations increase to replace sodium in the saliva when an animal is sodium deficient, altering the Na:K ratio (Underwood, 1981). McSweeney *et al*. (1988) also claimed that the Na:K ratio is a reliable method to measure the sodium status of animals. They mention aldosterone as another indicator of Na-status due to its role in the body's sodium conservation and its correlation to salivary sodium, potassium and the Na:K ratio of both goats and sheep. In their study, McSweeney *et al*. saw that when the Na:K ratio was less than 4:1, the concentration of aldosterone in the blood increased markedly. Morris and Peterson (1975) saw that cattle experiencing sodium deficiency can have Na:K ratios of less than 1:1 but McSweeney *et al*. (1988) conclude that ratios below 4:1 indicate deficiency. Farmers who have fast growing young animals on grain-based diets (especially when the plants are grown on a soil with low sodium content), lactating cows, or cattle in hot climates with high sweat losses should be observant for the absence to sodium (Underwood, 1981).

There are individual differences in how cattle respond when their sodium requirements are not fulfilled and they can be affected more or less and in different ways (Pehrson, 1983). Even when there are no visible symptoms of salt deficiency, it can cause an economical loss from reduced milk production and weight gain.

The symptoms of sodium deficiency in small ruminants are poor appetite, decreased weight gain and increased water intake (NRC, 2007b; Underwood, 1981). Decreases in weight gain depend partially on poor appetite but also on an impaired protein and energy metabolism. In goats, there are very few studies done. One of the few existing studies was performed by Schneller (1972, 1973) and he found that 1.7 g Na/kg DM was sufficient, while 0.3 g Na/kg DM was deficient for goats.

Sodium deficiency in horses results in a decreased rate of feed and water intake; however, clear symptoms take a long time to develop (Meyer *et al*., 1984). Horses are at a great risk to suffer sodium deficiency when they are trained intensively in hot environments and the losses of sodium through sweat lead to large ion deficits. A study on hard-working ponies, 2 hours trotting uphill, showed that it took 20-30 days before symptoms arise (Lindner *et al*., 1983). If sodium deficiency is acute, horses may exhibit uncoordinated movements and muscle contractions. It is important to know that there is a big difference in how much sodium horses lose depending on if they are used for hard work or only for walks in the forest. Carlson (1987) confirms that race horses lose large amounts of fluid, not only during the race, but also in connection with transport.

Excess

An excessive dietary intake of salt is detrimental to animal health as it can lead to reduced appetite or poor utilisation of feed and can damage their kidneys (ARC, 1980). When animals are fed excess salt, they can increase their water intake and urination rate up to a certain level to inhibit the surplus of sodium (NRC, 2007b). If salt intake approaches poisoning levels, one must correct electrolyte and fluid balance (Andersson, 1989).

Excess of sodium is not generally a problem as long as animals have free access to good quality water. The maximum level of sodium chloride in feed for dairy cattle is somewhere around 40 g NaCl/kg DM, almost 1 kg NaCl/day or 1.40 g NaCl/kg BW (NRC, 2001). That is a little higher than in humans, where a daily intake of 1 g NaCl/kg BW results in severe salt poisoning (Andersson, 1989).

Salt poisoning in veal calves is often caused by restricted access to water, but can be promoted by an excess of dietary sodium (Michell, 1985). Wamberg *et al.* (1985) studied 6-month-old Holstein-Friesian calves which were fed sodium hydroxide treated straw. Up to an allowance of 1.2 g Na/kg BW per day, there were no changes in the acid-base balance, electrolyte status or body growth rate. The only noticeable change was an increase in urine volume, probably as a result of mineral surplus excreted in the urine. Several other researchers (*e.g.* Meyer *et al*., 1955; Nelson *et al*., 1955) have made the same conclusion; ruminants can excrete massive dietary loads of Na and Cl as long as they have free access to water. Meyer *et al*. (1955) treated steers with 1.91 g NaCl/kg BW/day for 84 days without any harmful effects but they did observe a 50 % increase in water intake.

A horse can tolerate a maximum sodium concentration of 6 % in their feed (NRC, 2005). As long as the horse is supplied with ample water, the excess sodium will be excreted in the urine, like with the other species.

Saltfeeding

Two of the most common ways to offer animals sodium is either to give them salt blocks, or to add salt to their food (Jansson and Dahlborn, 1999). Farmers often add loose salt in the mixer wagon when preparing mixed feed for cattle, which is becoming all the more common. One method to test if the amount of salt is enough, is to put a saltlick in the milking plant. If the animals lick a lot, it can be an idea to enhance the amount of salt in the mix.

Langbein, Scheibe and Eichhorn (1998) wanted to see how frequently sheep visited a saltlick/feeding station and investigated the behaviour in free ranging mouflon sheep throughout the lambing season. By placing a tag around each sheep’s neck they were able to see when the sheep visited the combined saltlick/feeding station. The saltlick/feeding station was linked to a camera system so that they could count how often the sheep licked on the saltlick, which was regularly every two to three days.

Smith *et al*. (1953) performed one of the first studies on dairy cows' salt consumption. They wanted to see if the cows fulfilled their salt requirements from hard blocks. The study demonstrated that in two out of three years, lactating cows on pasture prefer loose salt to salt blocks. However, when the cows intake of salt came from salt blocks the intake was still sufficient to meet their requirements during lactation.

Andersson *et al*. (2006) wanted to see in which form horses prefer salt. The horses they offered saltlicks had an average intake of 18 g NaCl/day. They also offered horses salt loose in feed, although it was hard to measure intake because the salt absorbed moisture from the air. They mention this as one reason why the horses which were offered loose salt in the feed had a lower intake than the horses which were offered saltlicks. In the study, 12 of 16 horses met their sodium requirement from the feed and Andersson *et al*. believe this affected the horses' voluntary salt intake.

Jansson (1999) also wanted to see how horses respond to different strategies of sodium supplementation and if there are differences between voluntary systems or constant daily supply. The horses in their study had a voluntary sodium intake in the range of 0-62 mg/kg BW/day. The daily variation within the horses was small and the mean intake was not affected by feeding frequency. The horses with the lowest sodium intake had, as expected; the highest aldosteron concentrations in their blood. 6 out of 8 horses had unfulfilled sodium requirements. This is an indication that horses need to be fed salt in another form than saltlick if they are in training.

Feed intake is very important for animal production: it provides the animals with energy. Taste is of big importance and makes it possible to regulate feed intake by motivating animals to eat more (Goatcher and Church, 1970). The nature and temperature of the feed, as well as sex, age, experience and health of the animal are variables which may influence taste response. Salt is often used to influence an animal's feed intake. It can be used to make the feed more palatable but can also discourage feed intake if the amount added is very high.

The use of manufactured concentrates needs an observant farmer. The farmer has to know that the animals fulfil their requirements. Most concentrates have added salt and the cattle thereby get their sodium requirement fulfilled (Pehrson, 1983). In the mid-1960's, concentrate became all the more common as feedstuff and cattle quit utilising their saltlick because their sodium requirements were already fulfilled. As a result, farmers took away the saltlicks and forgot that animals have a sodium requirement. Later, farmers started to give high yielding cows feed for maximum yield with only 0.6 % salt content and steers feed concentrate without any salt at all. Consequently, problems such as decreased milk production arose. According to a study that dealt with comparative salt deficit, about one tenth of farmers in the Swedish county of Skaraborg fed their cattle a deficient amount of salt in the 1980's (Pehrson, 1983).

Salt in feeds

In most places around the world, pastures and grain are deficient in sodium with respect to animal needs (McDowell, 1997). The sodium content of pasture depends on plant species, soil type, and the amount of potassium added as fertiliser (Eriksson, 2005; Phillips *et al.* 2000). High levels of potassium reduce sodium uptake among plants. In most cases, sodium and chloride are more common in plants grown in coastal areas than grown inland (Staaland and

White, 2001). In the United Kingdom, the average sodium content for pasture is 2 g/kg dry matter (DM), while it is less than 1 g Na/kg DM in many tropical countries (Phillips *et al*., 2000; Sanchez *et al*., 1994). In the north of Sweden the average sodium content is only 0.2 g/kg DM (Eriksson, 2005). However, some feedstuffs has higher concentrations compared with others, for example beet sugar molasses with 11.5 g Na/kg DM (NRC, 2007a). For the sodium content in some common feedstuffs, see Table 1.

Tabel 1. The sodium content in some common animal feeds (Spörndly, 2003; Carlzon, 2008; Eriksson, 2005; Krafft, 2008; Phillips *et al*., 2000; Sanchez *et al*., 1994).

Feed	Sodium content g/kg DM
Grass	0.2-2
Straw	3.0
Silage Grass	1.5
Silage Clover	0.4
Silage Corn	0.4
Hay	1.5
Oat (with husk)	0.3
Barley	0.3
Wheat	0.2
Rapeseed	0.1
Sugar beet (molasses)	11.5
Peas	0.3
Rapeseedcake	0.5
Expro	0.5
Unik (dairy feed, commercial)	3.0
Solid (dairy feed, concentrate blends)	3.0
Krafft (horse feed, pellet)	3.1
Effekt (Mineral Feed)	70.0
Krafft (Mineral Feed)	49.0
Milk (Whole milk)	3.2

Sometimes the animals are fed Na-treated straw or grain, where the straw or grain is treated with sodium hydroxide (NaOH) to make it more digestible (Spörndly, 1997). De Campeneere *et al*. (2006) wanted to see how sodium hydroxide treatment of wheat affects feed intake, milk production and milk content in dairy cattle. The results indicate an increase in milk yield and high yield of fat and protein corrected milk. One problem is the risk for Na-excess and it is very important with free access to fresh water. On the market, there are mixed feeds available with no salt to prevent sodium excess when sodium hydroxide treated feeds are used.

Salt in water

Water quality is very important for producing and working animals. The sodium chloride content in water differs enormously depending on its source, from nearly nothing in streams to high concentrations from deep wells (Underwood, 1981). In the United States of America approximately 40 % of the livestock are watered from lakes, streams, springs and impoundments (Harris and Van Horn, 2008). Water can therefore, depending on the sodium concentration, be a valuable source of supplementary sodium in areas with low soil sodium, but there is also a risk for toxic values. If an animal has a high salt intake from feed, it can compensate through increasing its water intake and in that way increase the kidneys' salt excreting capacity. If the water has a high salt content this does not work and the animal cannot get rid of the surplus which leads to an increased risk for toxic levels.

The highest endurable salt content in water for cattle is somewhere around 0.5 % (Persson, 1983). According to Table 2, water with a salt content between 0.5 and 0.7 % should be avoided when cattle are pregnant or lactating (Linn *et al*., 1987). Sheep tolerate higher salt content in water than do other ruminants and can cope with 2.5 % (Olsson and Pehrson, 1984). Inland seawater can have very different salt contents, in some cases barely measurable. In cases where the sea is adjacent to open ocean, the salt content is much higher. The brackish water of the Baltic Sea has a salt content of between 0.3-0.7 %, depending on where and how deep the sample is taken as the salt content is highest close to the North Sea and near the bottom (Svedlindh, 2008).

Denton and Sabine (1961) state after trials on sheep, that an animal's willingness to drink Na-salt solutions depends on its sodium deficit. Among horses, there are big differences between individuals with respect to their willingness to drink the solution (Jansson *et al*., 1995; Meyer, 1987).

There are no distinct requirements for the quality of water, but Table 2 shows limiting values for total soluble salts (TSS). TSS is the total amount of ions in the water but the values can also be applied to saltwater.

Table 2. Limiting values of Total Soluble Salts (TSS) for cattle (Linn *et al*., 1987).

TSS, mg/l	%	Comments/Effects
<1000	0.1	Secure level. Does not cause health problems.
1000-2900	0.1-0.3	Generally secure. Can cause diarrhoea, occasionaly.
3000-4900	0.3-0.5	The water can be abandoned. Can cause diarrhoea. Production can decrease.
5000-6900	0.5-0.7	Avoid this water. Harmful to pregnant and lactating animals.

When formulating a feeding plan, it can be of interest to know how much salt there is in the water in order to calculate the sodium requirements. Animals requirements must be fulfilled entirely through feedstuff, special additives and the drinking water. Coppock *et al*. (1988) saw in their study that the cattle in Texas are fed nearly 170,000 tonnes of salt per year and suggest that farmers there reduce the use of salt, in some cases by up to 100 %.

Randall *et al.* (1978) wanted to see how the horse responds to sweet, salty, sour and bitter solutions with preference tests. In their study the horses were indifferent to NaCl up to a concentration of 0.63 g/100 ml water (0,63 %) when they started to avoid the solution. The solution was totally rejected at 1.25 to 2.5 g/100 ml (1.25 to 2.5 %). In conclusion, they mention that immature horses respond quite similarly to sheep in their taste behaviour but with variation among individuals.

Cattle and Small Ruminants

The function of sodium in the body

The absorption of minerals occurs either by simple diffusion, or through carrier mediated transport and the amount absorbed can affect the body's absorption of other minerals (NRC, 1996). In ruminants, sodium is absorbed in the rumen, omasum and intestines for an average total absorption of 91 %, although anywhere between 85 to 98 % is common. Sheep and goats absorb more sodium in the large intestine than cattle (White *et al*., 1984). This absorption advantage leads to higher DM content in the faeces among small ruminants.

In cattle, the concentrations of sodium in blood plasma are about 3.45 g/l and 3.22 to 4.14 g/l in saliva. The concentration in the milk is not affected by dietary sodium content and is between 0.50 and 0.69 g/l (NRC, 2001; Underwood, 1981).

Magnesium (Mg^{2+}) uptake from the rumen may respond negatively to feed with high amounts of potassium and low amount of sodium (Eriksson, 2005). Consequently, more sodium and less potassium in the rumen increases the absorption of magnesium and calcium (Ca^{2+}). This leads to a reduced prevalence of milk fever and grass tetany, diseases caused by low levels of magnesium and calcium in the body (Phillips, 2001). Chloride is absorbed differently in young and adult ruminants. In young animals it is absorbed in the small intestine, while in adult animals it is absorbed both in rumen and the small intestine (ARC, 1980; White *et al*., 1984).

Effects of sodium

Improved herbage digestibility and promoted growth of bacteria that digest fibres in the rumen can be the result when cows graze pastures fertilised with sodium (Phillips *et al*., 2000). The improved digestibility depends on more sodium being recycled in the saliva, which decrease rumen acidity, and that the cow spends more time ruminating. Sodium is an important in a ruminant's saliva to buffer acid against acid produced in ruminal fermentation (NRC, 2001).

Salt is used in many different ways in extensive grazing systems, for example to control the animals' grazing pattern and reduce feed intake. A common problem in extensive systems is that cattle use the land unevenly (Ganskopp, 2001). To optimise income, it is better if the cattle graze the pasture as uniformly as possible. After fencing, water and salt are two of the most frequently used tools to control the land use. Ganskopp (2001) showed, however, that water is better than salt and suggest not using salt as a tool for influencing the movement of livestock. Cardon (1953) wrote in his work that stockmen used high concentrations of salt to control the consumption of supplemental feed by grazing animals. They mixed salt with alfalfa hay, which was used as supplemental feed, and placed it in a self-feeder. Animals ate less, received as a result more equal rations and the farmer only needed to feed the animals approximately twice a week, thereby reducing labour costs by using salt.

Cardon (1953) also wanted to see how high salt intake affects cellulose digestion. Cellulose is an important source of energy for ruminants. In the rumen, micro-organisms break cellulose into simple carbohydrates. His work shows that the microbial activity in rumen is unaffected by the high salt intake. Digestible cellulose, digestible gross energy and pH in rumen after fermentation are equally unaffected by high salt intake. Consequently, Cardon wonders if the stockmen's method to reduce feed intake is reliable when the high salt intake does not influence digestion. Maybe salt works to control feed intake by making it less palatable.

Other researchers have also studied if a high sodium intake is unhealthy for the animals or influences digestibility. Meyer *et al*. (1955) showed that even when the sodium chloride level is 12.8 % of the ratio for sheep and 9.3 % of the ratio for cattle, there was no detectable influence on either total digestible nutrient content in the feed, or nitrogen digestibility and nitrogen retention. Some physiological changes among the experimental animals were found when they had a high intake of sodium: their kidneys increased in size, and fattening steers had a decreased carcass grade at the time of slaughter. The increased kidney size of the kidney can indicate that the kidneys worked too hard and that the animals may have suffered. Nelson *et al*. (1955) determined the influence of high salt intake (6 % of the ratio) on nutrient digestibility and also on nitrogen retention in steers and rams. In the steers, feed digestibility was not affected by high salt intake but in the rams it decreased the digestibility of organic matter and nitrogen free extract. In both steers and rams the high salt intake led to a significant increase in the retention of sodium and chloride. Almost all sodium and chloride, 87-98 %, were excreted in the urine in both species.

In several studies Phillips *et al*. (2000) studied the effects of sodium fertilisers and supplements on milk production and mammary gland health. They saw that on productive pastures, for example with natrophilic Perennial rye-grass, sodium fertilisers could increase the sodium content of the herbage and the milk yield of cows, while at the same time reducing the milk's somatic cell count (SCC). These effects depend to some degree on the increased digestibility of the herbage fertilised with sodium. On the other hand, on less productive pastures, for example natrophobic grasses and broad-leaved plants, sodium fertilisers did not affect the herbage sodium content, milk production or composition.

In one experiment, cows with individual feeding were fed an increased amount of sodium, from 1-6 or 11 g Na/kg DM, by adding salt (Phillips *et al*., 2000). This increase influenced both milk yield and SCC in a favourable way when the cows were given the high amount, 11 g Na/kg DM. When 6 g Na/kg DM were given, only SCC decreased. The increased amount of sodium also positively influenced the cow's calcium and magnesium status.

To analyse the recommended dietary sodium content, Phillips *et al*. (2000) increased the intake of sodium for cows from 2 to 3.6 g/kg DM. Such a treatment did not affect milk yield or SCC but did reduce *Staphylococcus aureus* contamination of the milk. After their experiments, Phillips *et al*., concluded that the recommended dietary sodium concentration of 1.3-1.8 g Na/kg DM is too low for grazing animals intended for maximum production. The authors recommend that the concentration of grazed herbage should be at least 4 g Na/kg DM.

Sodium content in sheep's milk is 0.4 g Na/kg (NRC, 2007b). Vincent *et al*. (1986; 1987) studied how Blackface sheep respond to sodium intake during two parities. They gave one group of ewes a diet low in sodium (69-161 mg/day, 253 mg/day during lactation) through two reproductive seasons. They also had a control group which was given the recommended level of sodium, tenfold that of the experimental diet. The ewes on the low-sodium diet had a very low excretion of sodium in urine and faeces, 69 mg/day, and had a significantly lower sodium concentration in the saliva. The pregnant and lactating ewes that received low sodium likely released sodium from their bones and thereby kept the sodium concentration in blood plasma and soft tissue at constant levels. Even though the sodium levels were constant and no changes in milk yield or concentration of sodium in the milk were observed, the study indicated that lambs born to ewes on low-sodium diets had a slower growth rate than lambs in the control group.

The effect of salt on ruminal turnover rates, acid-base balance and mineral status among lactating cows under heat stress were examined by Schneider *et al*. (1988). In an environment where cows experienced heat stress, one group of cows was fed a high mineral diet and one was fed a basal diet. Milk yield and DM intake were not affected by the high mineral intake but the cow's water intake increased.

Calves held in individual pens often spend a lot of time licking objects in the pen (Phillips *et al*., 1999). This is probably a result of a deficient supply of sodium and high stress levels. Stress increases sodium requirements and in other herbivores stress increases sodium appetite. This fact suggests that there is a physiological relationship between stress and sodium status which leads to stereotypies. Calves lick less when salt is added to their feed. Phillips *et al.* (1999) claim that stereotypies can be controlled by increased sodium intake. They based their statement on the fact that calves fed supplementary sodium spend less time licking the pen and bucket, sucking their ears and grooming themselves. The enhanced salt intake, however, leads to a larger water intake which in turn leads to increased urination. Increased urination can result in wet beddings, which is not so good as it is important to keep the beds dry for the calf.

Horses

The function of sodium in the body

The total sodium content of a horse is about 1 kg (Frape, 2004). 45 % is in the interstitial fluid, 45 % is in the skeleton and 10 % is in the cell plasma (Jansson, 1999)

Horses lose sodium through faeces and urine but mainly via sweat. An inactive horse has an endogenous sodium loss around 15-20 mg/kg body weight (BW) per day (7.5-10 g/day for a 500 kg horse) (Schryver *et al*., 1987). Horse sweat is hypertonic relative to blood plasma and contains a sodium concentration that ranges from 3.3 to 82.5 g/l (Jansson 1999, Meyer, 1987; Meyer, 1987). McConaghy *et al*. (1995) recognize that sweat secreted post-exercise has a higher sodium concentration. Sodium concentration in mare milk is 180 mg/kg the first three month after foaling but after 12-17 weeks it decreases to 115 mg/kg milk (Schryver *et al*., 1986)

A horse in hard training or in a race can lose up to 12 kg fluid and up to 130 g NaCl (50.7 g Na) per hour. Sodium intake does not impact sodium concentration in the horse's sweat (Meyer *et al*., 1984). A horse that sweats a lot during exercise is at risk for a negative water and electrolyte balance because of the substantial mineral loss (Snow *et al*., 1982). In humans, electrolytes can be reabsorbed in the sweat glands but this is not the case in horses and thus horses lose substantial amounts of electrolytes during sweating.

Balancing sodium loss during exercise

According to a study of standardbred horses by Jansson *et al.* (1995), fluid and total sodium losses in the sweat are around 45 % higher after exercise at 35 ^{o}C than at 20 ^{o}C. This is not remarkable, yet they also discovered that fluid losses were the same even when horses were loaded with salt before exercise. In their study, horses fed 32 mg salt/kg BW/day had positive sodium levels in their urine during test days, but almost no sodium excretion at all either immediately following exercise, or the next day. They also found that sweat loss was followed by lowered blood plasma sodium concentrations the day after exercise at 35 ^{o}C, indicating a sodium deficit in the body. A very important detection was made: even after minimal fluid loss (8 ± 0.5 kg), 38 g Na/day is not enough to replenish sodium within two days. They concluded that deficiency in sodium, which regulates osmotic pressure between blood and tissue cells, can lead to a decreased blood volume. If extracellular sodium concentrations are too low, water will pass from the interstitial fluid into the cell plasma, leading to cellular hypervolemia (Andersson, 1971). Long-running deficiency can affect the body's capacity to retain water, which results in reduced body weight. Jansson *et al.* recommend that horses be trained to drink saline solution and suggest that the athletic horse should be given supplemental salt on exercise days instead of high amounts every day. This is also something that Meyer (1987) recommends.

Litz (2003) studied how dietary salt affects acid-base balance in endurance horses. The horses were not negatively affected when they were given a salt treatment that exceeded their daily requirement for a long period. The study also showed that horses fed a high salt treatment cope better with salt and fluid losses during exercise than horses fed a low salt treatment. This study supports the findings of Jansson *et al*. (1995) that blood sodium content one day after exercise is below normal concentrations unless the horses have been fed supplemental sodium. Horses given a high salt treatment show higher and more stable concentrations of blood plasma electrolytes, both at rest and during exercise and have an increased ability to compensate for electrolyte losses.

In Jansson and Dahlborn's study (1999), water and sodium intake in horses were positively correlated, just like other studies have shown for other species (Meyer *et al*., 1955; Nelson *et al*., 1955). In their study, Jansson and Dahlborn did not measure total body water content or blood plasma volume but they presume that increased packed cell volume during exercise indicates that horses with a low sodium intake had a reduction in blood plasma volume and/or cellular hypervolemia.

Meyer *et al*. (1984) proved that inactive horses, with an intake of only 1.6 mg Na/kg BW/day, can adapt to a low sodium intake over time and have a positive sodium balance.

Recommendations

Getting to know the sodium requirement starts with a calculation of maintenance needs, to which additional needs are added.

Estimated requirements, with some allowances for variation, are often expressed as recommendations in national feeding systems. The following part is therefore focused on recommendations, which are the minimum intake required to provide good health and production (Michell, 1985). The recommended levels are mentioned in different ways for different animals as a matter of convention.

Cattle

The recommended sodium intake for dairy cows can be seen in Tables 3:1 and 3:2. NRC numbers are based on losses in the faeces and urine: total inevitable losses being 0.015 g/kg BW/day for growing cattle and non lactating cows and 0.038 g/kg BW/day for lactating cows (NRC, 2001). To the need for maintenance, a number of other needs are added, depending on the cow's status as is shown in Table 3:1. Environment is an important factor for sodium excretion; therefore, temperatures over 25 ^{o}C are included in Table 3:1.

Table 3:1. NRC (2001) -recommended daily sodium intake for dairy cows. All values are based on absorbed sodium and are calculated with an absorption coefficient of 90 %. BW stands for bodyweight

		Sodium
Maintenance	growing cattle and non lactating cows	1.67 g/100 kg BW
	lactating cows	4.22 g/100 kg BW
Growing		1.56 g/kg of average daily gain for animals weighing 150-600 kg
Pregnancy		1.54 g/d from 190-270 days of gestation
Lactating		0.70 g/kg milk
Environmental temperature	Between 25 and 30 ^{o}C	0.11 g/100 kg BW
	>30^{o}C	0.44 g/100 kg BW

Swedish recommendations are based on NRC recommendations, but expressed as g/kg DM intake (Table 3:2).

Table 3:2. The Swedish recommendations for sodium intake by dairy cows “Fodertabeller för idisslare” (Spörndly, 2003).

	Sodium
Dairy cows 10-30 kg milk	2.2 g/kg DM feed
Dairy cows >30 kg milk	2.2 g/kg DM feed
Dry cows	1.0 g/kg DM feed

The NRC-recommended sodium intake for beef cattle can be seen in Table 4.

Table 4. NRC (1996) -recommended sodium intake for beef cattle, % of total feed intake per day.

	Sodium
Nonlactating beef cattle	0.06-0.08 %
Lactating beef cows	0.10 %

The Swedish recommendations for beef cattle are the same as for dry cows presented in Table 3:2.

Small Ruminants

When estimating total daily sodium requirement for small ruminant’s, endogenous sodium losses are to be considered. Sodium requirements for weight gain, late pregnancy and lactation are added to the true absorption rate of 0.91 (NRC, 2007b). This is calculated by the NRC and the results for sheep can be see in Table 5:1, while the Swedish recommendations are presented in Table 5:2. Like with cows, one must add these needs to the sodium requirements for maintenance.

Table 5:1. NRC (2007b) -recommended sodium intake for sheep, expressed as g/day.and assuming 0.91 is the absorption rate.

		Sodium
Maintenance		(0.0108 g * BW)/0.91
Growing		(1.1 g * average daily weight gain (DWG))/0.91
Pregnancy	105-133 days	(0.021 g * lamb born weight (LBW)/0.91
	133-147 days	(0.013 g * LBW)/0.91
Lactating		(0.4 g * milk yield (MY))/0.91

In Swedish recommendations, sodium intake is expressed in terms of common salt and not in sodium requirement, see Table 5:2. 10 g salt has a sodium content of 3.9 g.

Table 5:2. The Swedish recommendations for salt intake by sheep "Fodertabeller för idisslare" (Spörndly, 2003)

	Salt
Maintenance	10 g/day
Lactating ewes	1.5 g/lamb and day

For goats, the absorption rate is slightly lower than for sheep: around 80 % of the sodium is absorbed (NRC, 2007b). NRC-recommended sodium intake for goats can be seen in Table 6:1 and the Swedish recommendations in Table 6:2.

Table 6:1. NRCs (2007b) recommended sodium level to goats, g/day

		Sodium
Maintenance		(0.015 * BW)/0.80
Growing		(1.6 * average DWG)/0.80
Pregnancy	105-133 days	(0.034 * (LBW))/0.80
Lactating		(0.4 * MY)/0.80

Again with goats, the Swedish recommendations are expressed in common salt and not in sodium, see Table 6:2.

Table 6:2. The Swedish recommendations for sodium intake by goats "Fodertabeller för idisslare" (Spörndly, 2003).

	Salt
Maintenance	10 g/day
Lactating	1.5 g/kg milk

Horses

According to NRC (2007a) calculations, the optimal sodium concentrations in horse feed are 1.6-1.8 g Na/kg DM for growth, maintenance and late gestation and 3.6 g Na/kg DM for moderate to heavy work. The NRC (2007a) based its sodium intake recommendations (see Table 7) on a 90 % sodium absorption rate and endogenous losses of 18 mg/kg BW/day.

Unlike previous tables, it is not necessary to add further needs to the maintenance cost calculations as each requirement is calculated separately.

Table 7. NRC (2007a) -recommended sodium intake for horses, based on 90 % sodium absorption and an endogenous loss of 18 mg/ kg BW/ day. Needs are expressed in g/kg BW/day

		Sodium
Maintenance		0.02 g * kg BW
Growing		(0.02 g * kg BW) + (1.0 g * average daily gain in kg)
Pregnancy	Month 1-9	0.02 g
	Month 9-11	(0.022 g * kg BW)
Lactating	Foaling-3 month	(0.02 g * kg BW) + (0.032 g * kg BW * 0.17)
	4-5 month	(0.02 g * kg BW) + (0.026 g* kg BW* 0.14)
	After 5 month	(0.02 g * kg BW) + (0.020 g * kg BW * 0.14)
Exercise		(0.02 g * kg BW) + (3.1 g * kg BW loss during exercise)

In Table 8:1 and Table 8:2, the Swedish sodium recommendations for horses are presented (Jansson 2004). How much a horse sweats is determined from its energy intake.

Table 8:1. Recommended minimum intake from the total ratio, g/MJ

	Sodium
Maintenance	0.20 g / MJ
Pregnant (1 month-weaning)	0.20 g / MJ
Lactating (3-36 month)	0.15 g / MJ
Young horse (growing)	0.10 g/ MJ

The needs from Table 8:2 have been added to the maintenance needs in Table 8:1 for the days when the training has occurred.

Table 8:2. Sodium chloride losses during different work that needs to be compensated for.

Work		**Sodium chloride losses**
30 min. trot	warm summer	8 g/100 kg BW
Fast work (trot-gallop horses)	winter/autumn	17 g/100 kg BW
	warm summer	27 g/100 kg BW
Eventing	warm summer	35 g/100 kg BW
Endurance		45 g/100 kg BW

The NRC (2001) -recommended chloride intake for horses is 80 mg/kg BW/day. Often, it is presumed that a horse's chloride requirements are met when its sodium requirement are satisfied with sodium chloride. Again, this is because chloride requirement have not been strongly established.

In practise

To fulfil its sodium requirements, animals are often, as mentioned before, offered a saltlick or salt mixed in feed. The question is if they consume enough of the saltlick, or if the farmer adds enough salt in the feed to meet requirements.

In the calculations below, values from the former chapter are used.

Cattle

A dairy cow that weighs 650 kg and produces on average 31 kg energy-corrected milk (ECM)/day needs to have an intake of 231 MJ/day to meet her energy requirements (Spörndly, 2003). If the cow is pregnant, one must make an addition for pregnancy in months 7, 8 and 9. For heifers, one must add for their growth.

To cover its energy requirements, a cow has to have an intake of approximately 22 kg DM/day if the feed has a metabolizable energy around 10.5 MJ (Spörndly, 2003). The sodium requirement for such a cow is 49.1 g Na/day (0.076 g Na/kg BW) according to NRC (2001) and 48.4 g Na/day (0.074 g Na/kg BW) according to Spörndly (2003). To see if the sodium requirements are fulfilled with the feed some typical feeding plans are used; one ration with forage and 100 % commercial concentrate, one ration with home-grown grain and less commercial concentrate and one organic ration (Appendix 1).

The cow on 100 % commercial concentrate has an intake of 11 kg DM silage and 11 kg DM of the concentrate Solid per day. This leads to a sodium intake of 45.1 g/day.

The cow on the diet with grain and concentrate has an intake of 11 kg DM silage, 6 kg DM grain, 5 kg DM of the concentrate Unik and 0.15 kg DM of the mineral feed Effekt per day. With this feeding plan, the sodium intake is slightly lower, 41.8 g/day.

The cow on the organic diet has an intake of 12 kg DM silage, 6 kg DM grain, 2 kg DM peas, 1 kg DM rapeseed cake and 0.15 kg DM of the mineral feed Effekt per day. This feeding plan provides the lowest sodium intake, 31.4 g/day.

From this information, we can say that the sodium requirements are not fulfilled according either to NRC (2001) or Spörndly (2003) in any of the feeding plans. Our calculations of the sodium deficit in are presented in see Table 9.

Table 9. Sodium deficit according to three different feeding plans for dairy cows with reference to National Research Council and Swedish recommendations.

Feeding plan	**NRC (2001)** **Sodium deficit [g/day]**	**Spörndly (2003)** **Sodium deficit [g/day]**
100 % comm. conc.	4.0	3.3
Grain and concentrate	7.3	6.6
Organic	17.7	17.0

According to Table 9, the sodium deficit in the different cow diets ranges between 3.3 and 17.7 g/day. This means that the cows must consume 8.5 to 45.3 g salt/day from other sources in order to fulfil their requirements (Appendix 1). If the extra salt is provided by saltlick this means that cows on a 100 % commercial concentrate diet have to consume one 2 kg saltlick every 235 days (calculated according to Spörndly, 2003). This is feasible. Cows on the organic diet have to consume a saltlick every 44 days (calculated according to NRC 2001). This is not really realistic and therefore salt should be added in other forms.

Small Ruminants

Sheep

A ewe that weighs 50 kg 6 weeks before lambing (two lambs) has an energy requirement of 12.4 MJ/day (Spörndly, 2003). Such a ewe has to have an intake of 1.3 kg DM/day to fulfil its energy requirements. This is distributed as 1 kg DM silage/hay, 0.2 kg DM grain, 0.2 kg DM straw and 0.04 kg DM Expro per day.

The Swedish sodium recommendation for this ewe, as long as she not is lactating, is 3.9 g/day (0.078 g Na/kg BW). With the above feeding plan, the sodium intake per day is 2.2 g. The recommendations for a ewe 6 weeks before lambing are not fulfilled: it lacks 1.7 g Na/day. The NRC (2007b) recommendation is 1 g sodium for maintenance per day (0.02 g Na/kg BW). To adjust for pregnancy, one has to know the lambs born weight. It was assumed that the lambs weighed 4.5 kg at birth, which resulted in an additional requirement for pregnancy of 0.2 g Na/day. The NRC recommendation is 1.2 g sodium/day, which is fulfilled with the feed.

1.7 g sodium/day, which was lacking according to the Swedish recommendations, is equivalent the consumption of one 2 kg saltlick every 458 days for one ewe.

Goats

A goat's sodium requirement for maintenance is 3.9 g/day according to the Swedish recommendations (Spörndly, 2003) and the energy requirement is 7.4 MJ/day for a 50 kg goat. A lactating goat has a feed intake of approximately 1 kg DM hay and 2 kg DM grain or concentrate per day. With this feed intake, the sodium intake is 2,1 g/day. An additional 3,5 g sodium/day are required for lactation, if the milk yield is 6 kg, making the total sodium requirement for this goat 7,4 g Na/day (0,15 g Na/kg BW), resulting in deficit of 5,3 g Na/day.

According to NRC recommendations, a lactating goat has a total sodium requirement of 3.9 g/day (0.078 g Na/kg BW) if the milk yield is 6 kg. Maintenance requires only 0.93 g sodium/day compared to the Swedish recommendations 3.9 g Na/day. A deficit of 1.8 g sodium/day differs quite a lot from the Swedish recommendation (Spörndly, 2003). According to the Swedish recommendation, the goat must consume one 2 kg saltlick every 147 days, but only every 433 days according to the NRC.

Horses

A horse's sodium requirement depends mainly on how hard it is trained, to be more precise, on how much it sweats. The energy a horse requires to fulfil its energy requirements also depends on training. Hard training is a stress on the body, especially when training close to physiological limits. A horse in normal training that weighs 500 kg has an energy requirement of 65.2 MJ/day, while a horse in hard training has an energy requirement of 120.5 MJ/day.

According to Jansson (2004), a horse in normal training has to have an intake of 13 g Na/day (0.026 g Na/kg BW) but only 10 g Na/day (0.02 g Na/kg BW) according to the NRC (2007a) to fulfil its sodium requirement. A horse in hard training has to have an intake of 41 g Na/day (0.082 g Na/kg BW) according to the NRC (2007a) and 46.2 g Na/day (0.066 g Na/kg BW) during fast work in the winter/autumn according to Jansson (2004).

A horse in normal training has a feed intake of 5 kg DM hay or silage, 1.5 kg DM grain and 0.1 kg DM minerals per day, resulting in a sodium intake of 12.9 g/day. A horse in hard training has to have a higher intake to meet its energy requirements and eats 8 kg DM hay or silage, 1.5 kg DM grain, 3 kg DM concentrate and 0.1 kg DM minerals. The horse in hard training has an intake of 26.7 g Na/day.

A horse in normal training has its sodium requirements almost fulfilled according to both Swedish (Jansson, 1999) and NRC (2007a) recommendations. A horse in hard training lacks 14.3 g Na/day according to the NRC and 19.5 g Na/day according to Jansson (1999). As suspected, sodium intake is not enough to cover the requirement for horses in hard training.

If a horse in hard training is offered a saltlick to fulfil its sodium requirement, it must have an intake of 36.7 g salt/day from the saltlick according to the NRC and 50 g salt/day according to Jansson (1999). According to studies on the willingness of horses to consume sodium, consumption varies from 0-31 g Na/day (0-79 g NaCl/day) (Jansson and Dahlborn, 1999). This indicates that a horse in hard training could satisfy its sodium requirements as long as it is willing to like the saltlick.

Discussion

Salt is an essential element in the diet of animals and work has been done to understand how much different animals need and what happens if they get too little or too much. Many of the studies have been performed on animals deficient in salt and therefore do not describe the intake, metabolism and behaviour of animals when their salt requirements are satisfied. This can result in a distorted understanding of the truth. Michell (1989) states that published sodium requirements are often overestimated. He bases his statement on the fact that many of the studies are related to hyper acute and heavy shortage of sodium and he claims that mature mammals with no reproductive demands do not need more than 13.8 mg/kg BW/day and can probably manage with much less. Even institutions like the NRC call for more research in the field to better understand animals' maintenance requirements and sodium absorption (NRC, 2001).

There is a shortage of studies on how much sodium or salt animals can metabolise and what can influence metabolisation. Of course, there are individual differences and some animals will lick their saltlick until it is devoured, regardless of demand. In "Nutrient Requirements of Beef Cattle" (NRC, 1996) it is stated that ruminants have an appetite for sodium and that if they are provided sodium *ad libitum*, they will consume more than they need. Some researchers try to influence sodium intake using different flavouring so that the animals that do not otherwise devour their saltlicks will become more interested. At the University of Southampton, some researchers wanted to try which flavours horses prefer (Goodwin *et al*., 2005). In their short term trials, flavour influenced feed intake. The flavour fenugreek was most popular, followed by banana, cherry, rosemary and finally, quite surprisingly, carrot in sixth place. Maybe this strategy can be transferred to saltlicks, but more research is needed.

Animals that graze meadows close to the sea are often not provided with any other source of water to drink. The salt content of the seawater can be of interest, especially for cattle that are pregnant or lactating. Salt content above 0.5-0.7 % can be a health risk and should be avoided. This is something important to think about and put in relation to the salt intake from the feed.

Research about deficiency and excess of chloride is, as mentioned already in the text, not that easy to find. It is usually argued that if the sodium requirement is fulfilled, the chloride requirement will also automatically be satisfied. However, the Salt Institute refers to a Belgian study that indicates a correlation between chloride and potassium in cow urine. A diet high in potassium, as in most feedstuff for cattle, can increase the chloride requirement substantially. In small ruminants, chloride deficiency has never been observed, but in horses it is correlated to metabolic acidosis. With so little research, it is hard to know how animals react to a deficiency or excess of chloride. Can it be of more interest than presumed?

In the section "In practise", the question whether animals lick their saltlick sufficiently was answered. However, it just shows how one can use the recommendations to calculate sodium requirements for animals in a certain state and compare them with real intake from a few feeding plans. In reality, animal feeding plans vary greatly between different farms and it is not easy to calculate a general plan. When the calculations were performed, some difficulties were discovered: for example, one has to know lamb born weight to calculate the sodium requirement for pregnant sheep and goats. Assuming lamb born weight is not without its difficulties. It is also hard to calculate sodium recommendations for horses in hard training, as they depend on how much the horse loses in sweat during a race or workout. In the Swedish recommendations, there are some general numbers but horses are individuals and exhibit variation accordingly. One also has to estimate the actual work performed, which can lead to errant recommendations. Another problem for farmers with animals in extensive grazing systems, is that it is always hard to know what the animals actually eat (McSweeney *et al.*, 1988). Sodium intake and requirement are both dependent on housing and it is much easier to calculate them for intensive feeding systems than for grazing animals.

The sodium recommendations per kg BW do not differ much between lactating cows and horses in hard training according either to the NRC, or Swedish recommendations. Even the sodium requirements for goats according to the NRC and sheep according to Swedish recommendations are similar, ranging between 0.066-0.082 g Na/kg BW. The recommended sodium level for goats according to Swedish recommendations differ from the NRC by as much as 0.15 g Na/kg BW. The recommended level for sheep according to NRC is low, 0.02 g Na/kg BW. Both goats and sheep have very low sodium maintenance requirements according to the NRC and Swedish recommendations. The source for the Swedish recommendations for sheep and goats is not stated (Spörndly, 2003).

Increased herbage digestibility, promoted growth of bacteria that digest fibres in the rumen, increased milk yield and decreased SCC are results of using sodium as a fertiliser according to one author. In a long perspective sodium as a fertiliser may have a future even at Swedish latitudes due to climate change if farmers start growing grasses similar to those grown in southern Europe, for example more productive pasture species like the natrophilic Perennial rye-grass. Sodium can be a complement to fertiliser and thereby influence the over-fertilisation of phosphor, nitrogen and potassium in a positive way. It should be remembered however, that this pasture species are less productive than those common in the Nordic countries.

The signs of sodium and chloride deficiency are not easy to detect. Animals develop reduced appetites, growth rates and production, which are also indications of other deficiencies or diseases. It is likely that sodium deficiency is never established as a reason for production losses. To discover sodium deficiency and to measure an animal's sodium status, there is no completely reliable method. One method is to use the Na:K ratio in the saliva but more research is needed. Michell (1985) claims that sodium is one of the most important areas for research in agricultural economics.

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References

Andersson, B. 1971. *Thirst- and brain control of water balance*. Am Sci 59, 408-415.

Andersson, G., Hedhammar, Å., Holmgren, A., Persson, H. & Tjälve, H. 1989. *Förgiftningspanoramat hos djur*. Svensk Veterinärtidning, vol 41, Suppl. 19, 5-37.

Andersson, H., Westberg, J. & Öjetoft, L-M. 2006. *En jämförande studie av frivilligt intag av löst resp. fast salt hos normalt arbetande hästar*. Hippologenheten. Sveriges Lantbruksuniversitet. Strömsholm. Fördjupningsarbete nr 295.

ARC. 1980. *The Nutrient Requirements of Ruminant Livestock*. Slough, UK: Commonwealth Agricultural Bureaux.

Bell, F. R. and Sly, J. 1983. *The olfactory detection of sodium and lithium salts by sodium deficient cattle*. Physiology & Behavior, Volume 31, Issue 3, 307-312.

Bott, E., Denton, D. A., Goding, J. R. and Sabine. J. R. 1964. *Sodium deficiency and corticostereoid secretion in cattle. Nature*. UK. 202, 461-463.

Cardon, B. P. 1953. *Influence of a High Salt Intake on Cellulose Digestion*. J. Anim Sci. 12, 536-540.

Carlson, G. P. 1987. *Hematolgy and body fluids in the equine athlete: A review*. In: Equine Exercise Physiology. Ed. Gillespie, J. R & Robinson, N. E. ,393-425. ICEEP Publications, Davis, California.

Carlzon, B. Animal advisor. LG Husdjurstjänst. 013-31 75 67, 070-637 51 90. Personal messages. 2008-05-26

Coppock, C. E., Windle, L. M., Wilks, D. L., Woelfel, C. G. and Greene, L. W. 1988. *Addition of salt to cattle diets based on sodium and chloride in feedstuffs and drinking water*. J. Anim. Sci. 66, 1592-1597.

De Campeneere, S. De Boever, J. L. and De Brabander D. L. 2006. *Comparison of rolled, NaOH treated and ensiled wheat grain in dairy cattle diets.* Livestock Science Volume 99, Issues 2-3, 267-276

Denton, D. A., and Sabine J. R. 1961. *The selective appetite for Na+ shown by Na+ deficient sheep*. J. Physiol. 167, 97-116.

Eriksson, H. 2005. *Mineraler – vallfodrets innehåll och mjölkkornas behov*. Instutitionen för norrländsk jordbruksvetenskap. http://www.njv.slu.se/Husdjur/Nytt-hd305.pdf. 2008-03-16.

Frape, D. 2004. *Equine nutrition and feeding*. 3e ed. Blackwell Publishing, Iowa, USA.

Ganskopp, D. 2001. *Manipulating cattle distribution with salt and water in large arid land pastures: a GPS/GIS assessment*. Applied Animal Behaviour Science, 73, 251-262.

Goodwin, D., Davidson, H. and Harris, P. 2005. Selection and acceptance of flavours in concentrate diets for stabled horses. Applied Animal Behaviour Science, Volume 95. Issue 3-4, 223-232.

Goatcher, W. D. and Church, D. C. 1970. Review of some nutritional aspects of the sense of taste. J. Anim Sci. 31, 973-981.

Harris, B. Jr. and Van Horn, H. H. *Water and Its Importance to Animals*. University of Florida. http://edis.ifas.ufl.edu/DS085. 2008-03-16

Hollum, J. R. 1998. *Fundamentals of general organic and biological chemistry*. 6th ed. John Wiley & Sons, Inc, Torornto. Canada.

Jansson, A. 1999. *Sodium and Potassium Regulation. With special reference to the Athletic Horses*. Doctoral thesis. Agraria 179. Department of Animal Physiology. Swedish University of Agricultural Sciences. Uppsala.

Jansson, A. & Dahlborn, K. 1999. *Effects of feeding frequency and voluntary salt intake on fluid and electrolyte regulation in athletic horses*. J Appl Physiol, 86, 1610-1616.

Jansson, A., Nyman, S., Morgan, K., Palmgren-Karlsson, C., Lindholm, A. & Dahlborn, K. 1995. *The effect of ambient temperature and saline loading on changes in plasma and urine electrolytes (Na+ and K+) following exercise*. Equine vet. J., Suppl. 20, 147-152.

Jansson, A. 2004. *Utfodringsrekommendationer för häst*. Sveriges Lantbruksuniversitet.

Kurlansky, M. 2002. *Salt - En världshistoria*. Ordfront förlag, Stockholm.

Krafft, http://www.krafft.nu/default.asp?menuItem=3. 2008-05-26

Langbein, J., Scheibe, K.-M. and Eichhorn, K. 1998. *Investigations on periparturient behaviour in free-ranging mouflon sheep (Ovis orientalis musimon).* J. Zool., Lond., 244, 553-561.

Lindner, A., Schmidt, M. and Meyer, H. 1983. *Investigations on sodium metabolism in exercised Shetland ponies fed a diet marginal in sodium*. In: Equine Exercise Physiology. Eds: D.H. Snow, S.G.B Persson and R.J Rose. Granata Editions, Cambridge. 310-317.

Linn, J. G., Plegge, S. D.,Otterby, D. E. and Hansen, S. A. 1987. *Water: Quality and importance of dairy and beef production*. Dept. of animal science. University of Minnesota.

Litz, P. 2003. *Effekten av fodrets saltinnehåll på syra-basbalansen hos distanshästar.* Examensarbete. Instutitionen för anatomi och fysiologi. Sveriges Lantbruksuniversitet. Uppsala. Rapport nr 52 (2003).

McConaghy, F. F., Hodgson, D. R., Evans, D.L. and Rose, R. J. 1995. *Effect of two types of training on sweat composition*. Equine Vet J Suppl. 18, 285-288.

McDowell, L. R. 1997. *Minerals for Grazing Ruminants in Tropical Regions*. 3rd ed. Bulletin. Gainesville: University of Florida. 81.

McSweeney, C. S., Cross, R. B., Wholohan, B. T. and Murphy, M. R. 1988. *Diagnosis of sodium status in small ruminants*. Aust. J. Agric. Res. 39, 935-942.

Meyer, J. H., Weir, W. C., Ittner, N. R. and Smith, J. D. 1955. *The influence of high sodium chloride intake by fattening sheep and cattle*. J. Anim. Sci. 14, 412-418.

Meyer, H., Schmidt, M., Lindner, A. and Pferdekamp, M. 1984. *Beitrage zur Verdauungsphysiologie des Pferdes, 9. Einflkuss einer marginalen Na-versorgung auf Na-Bilanz. Na-Gehalt im Schweiss sowie klinische Symptome. Z.* Tierphysiol. Tierernahr. Futtermittelkd. 51, 182-196.

Meyer, H. 1987. *Nutrition of the equine athlete*. Equine Exercise Physiology II. 644-673.

Michell, A. R. 1985. *Sodium and research in farm animals: problems of requirement, deficit, and excess*. Outlook Agric. 14, 179-82.

Michell, A.R. 1989. *Physological aspects of the requirement for sodium in mammals*. Nutrition Research Reviews, 2, 149-160.

Morris, J. G. 1980. *Assessment of sodium requirements of grazing beef cattle: a review*. J. Anim. Sci. 50, 145-152.

Morris, J. G. and Peterson, R. G. 1975. *Sodium requirements of lactating ewes. Journal of Nutrition*. 105, 595-598.

Nelson, A. B., MacVicar, R. W., Archer, W. Jr. and Meiske, J.C. 1955. *Effect of a high salt intake on the digestibility of ration constituents and on nitrogen, sodium, and chloride retention by steers and wethers*. J. Anim Sci. 14, 825-830.

NRC. 1996. *Nutrient requirement of Beef cattle*. National Research Council. National Academic Press, Washington DC.

NRC 2001. *Nutrient requirements of Dairy cattle*. 7th rev. ed. National Research Council. National Academic Press, Washington DC.

NRC. 2005. Mineral Tolerance of Animals, 2nd rev. ed. The National Academic Press. Washington, DC.

NRC. 2007a. *Nutrient requirements of Horses*. 6th rev. ed. National Research Council. National Academic Press, Washington DC.

NRC. 2007b. *Nutrient requirement of Small Ruminants: sheep, goats, cervids and new world camelids*. National Research Council. National Academic Press, Washington DC.

Olsson, T. and Pehrson, B. 1984. Saltvattentolerans hos får. Svensk Veterinärtidning 36:12, 557-560.

Persson, L. 1983. *Forskning och praktik, 2: Dricksvatten åt husdjur*. Statens Lantbruksinformation.

Pehrson, Bo. 1983. *Får dina kor tillräckligt med salt?*. VL-tidningen, nr. 4 (1983). 26-28.

Phillips, C. J. C. 2001. Principles of Cattle Production.

Phillips, C. J. C., Youssef, M. Y. I., Chiy. P. C. and Arney, D. R. 1999. *Sodium chloride supplements increase the salt appetite and reduce stereotypies in confined cattle*. Animal Science 68, 741-748.

Phillips, C. J. C., Chiy, P. C., Arney, D. R. and Kärt, O. 2000. *Effects of sodiumfertilizers and supplements on milk production and mammary gland health*. Journal of Dairy research 67, 1-12.

Puls, R. 1994. *Minerals Levels of Animals Health: Diagnostic data*. Clearbrook, British Columbia: Sherpa Int.

Randall, R. P., Schurg, W. A. and Church D. C. 1978. *Response of Horses to Sweet, Salty, Sour and Bitter Solutions*. J. Anim Sci. 47, 51-55

Robbins, C. T. 1993. Wildlife Feeding and Nutrition. 2nd ed. New York: Academic Press. 44-52.

Sanchez, W. K., McGuire, M. A. and Beede, D. K. 1994. *Macromineral nutrition by heat-stress interactions in dairy cattle – review and original research*. Journal of Dairy Science 77, 2051-2079.

Salt Institute. *History of salt*. [http://www.saltinstitute.org/38.html] 2007-12-11

Schneider, P. L., Beede, D. K. and Wilcox, C. J. 1988. *Effects of Supplemental Potassium and Sodium Chloride Salts on Ruminal Turnover Rates, Acid-Base and Mineral Status of Lactating Dairy Cows During Heat Stress*. J. Anim Sci. 66, 126-135.

Schryver, H.F., Oftedal, O.T., Williams, J., Soderholm, V. and Hintz, H.F. 1986. *Lactation in the horse: the mineral composition of mare´s milk*. J. Nutr. 116, 2142-2147

Schryver, H.F., Parker, M. T., Daniluk, P. D., Pagan, K. I., Williams, J., Soderholm, L. V. and Hintz, H. F. 1987. *Salt consumption and the effect of salt on mineral metabolism in horses.* Cornell Vet, 77. 122-131.

Snow, D. H., Kerr, M. G., Nimmo, M. A. and Abbott, E. M. 1982. *Alterations in blood, sweat, urine and muscle composition during prolonged exercise in the horse*. Vet. Rec. 110, 377-384.

Smith, S. E., Lengemann E. W. and Reid J. T. 1953. *Block vs. loose salt consumption by dairy cattle*. Journal of Dairy Science, Vol. 36, 7, 762-765.

Staaland, H. and R. G. White 2001. *Regional variation in mineral contents of plants and its significance for migration by Arctic reindeer and caribou*. Alces. 37, 497-509.

Spörndly, R. 1997. Betydelsen av mineralämnen och spårelement i vallfoder. Växteko, Växtpressen. Hydro Agri AB.

Spörndly, R. 2003. *Fodertabeller för idisslare*. Sveriges Lantbruksuniversitet. Instutitionen för husdjurens utfodring och vård. Rapport 257.

Svedlindh, C. 2008. Enhetschef, Naturvårdsdirektör, Länsstyrelsen i Östergötland. 013-19 65 04, 070-380 65 04. Personal message.

Swedish Dairy Association. 2007. *Mjölk i siffror*. Rolf Tryckeri ab, Skövde.

Underwood, E. J. 1981. *The Mineral Nutrition of Livestock*. 2nd ed. Slough, UK: Commonwealth Agricultural Bureaux.

Vincent, I. C., Williams, H. LI. and Hill, R. 1986. *Effects of sodium intake on lactation and Na levels in body fluids of Blackface ewes*. British Journal of Nutrition 56, 193-198.

Vincent, I. C., Michell, A. R., Williams, H. LI. And Hill, R. 1987. *Effects of sodium intake during two parities on Na status in Blackface sheep*. British Journal of Nutrition 57, 447- 455.

Wamberg, S. Engel, K. and Stigsen, P. 1985. *Acid-base balance in ruminating calves given sodium hydroxide-treated straw*. British Journal of Nutrition 54, 655-661.

White, R. G., Jacobsen, E., and Staaland, H. 1984. *Secretion and absorption of nutrients in the alimentary tract of reindeer fed lichens or concentrates during the winter.* Can. J. Zool. 62, 2364-2376.

Appendix

Appendix 1. Cattle

Tabel 10:1. Total mixed ratio (TMR)

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage	1.5[1]	11	16.5
Grain	0.3[1]		0
Solid	2.6	11	28.6
Unik	2.6		0
Effekt	0.15		0
Total		22	45,1

[1] From Spörndly (2003)

Tabel 10:2. Grain and concentrate.

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage	1.5	11	16.5
Grain	0.3	6	1.8
Solid	2.6		0
Unik	2.6	5	13
Effekt	70	0.15	10.5
Total		22.15	41.8

[1] From Spörndly (2003)

Tabel 10:3. 100 % organic.

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage	1.5	12	18
Grain	0.3	6	1.8
Peas	0.3	2	0.6
Rapeseedcake	0.5	1	0.5
Solid	2.6		0
Unik	2.6	0	0
Effekt	70	0.15	10.5
Total		21.15	31.4

[1] From Spörndly (2003)

Table 11. Salt one must add to fulfil cattle sodium requirements for different feeding plans

Feeding plan	Salt g/day
NRC (2001)	
TMR	10.3
Grain and concentrate	18.7
Ecological	36.9
Spörndly (2003)	
TMR	8.5
Grain and concentrate	16.9
Ecological	35.1

Small ruminants

Sheep

Maintenance: 0,395 MJ/kg $BW^{0,75}$; $0,395 * 50^{0,75} = 7,4$ MJ/day
Pregnancy: 6 weeks before lambing 5,0 MJ/day

Table 12. Feed and sodium intake by sheep

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage/Hay	1.5[1]	1	1.5
Grain	0.3[1]	0.2	0.06
Straw	3	0.2	0.6
Expro[2]	0.5	0.04	0.02
Total		1.44	2.18

Goats

Maintenance: 0.395 MJ/kg $BW^{0.75}$; $0.395 * 50^{0.75} = 7.4$ MJ/day

Horses

Tabel 13:1. Normal training, Jansson (2007a)[1]

	Energy requirements, MJ
Maintenance	53[2]
Work walk 30 min	2.9[3]
trot/canter 10 min	9.3[4]
Total	65.2

[1] The horse is trained 1 hour 5 times per week, 40 minutes walking and 20 minutes trotting and cantering.
[2] $(0,5 * 500^{0.75}) = 53$ MJ
[3] (40 min * 5 days/ 7 days per week) = 28.6 min/day, 0.2 MJ/100 kg body weight and 10 min (0.2 * 5 * 2.86) = 2.9 MJ
[4] (20 min * 5 days/ 7 days per week) = 14.3 min/day, 1.3 MJ/100 kg body weight and 10 min (1.3 * 5 * 1.43) = 9.3 MJ

Tabel 13:2. Hard training, Jansson (2007a)[1]

	Energy requirements, MJ
Maintenance	53
Work	67.5
Total	120.5

[1] Fast work several times per week
[2] 13.5 MJ/100 kg body weight, 13.5 * 5 = 120.5

Table 14:1. Feed and sodium intake by a horse in normal training

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage/Hay	1.5[1]	5[4]	7.5
Grain	0.3[1]	1.5[5]	0.45
Concentrate	-		0
Minerals[2]	49	0.1	4.9
Total		6.6	12.9

[1] From Spörndly (2003)
[2] Krafft Miner blå pellets, 125 g salt/kg; 125*0.39 = 49
[3] Approximately 10 MJ/kg DM in silage (Spörndly, 2003)
[4] Minimum 1 kg DM/ 100 kg body weight and day.
[5] Oats 11.7 MJ/kg DM

Table 14:2. Feed and sodium intake by a horse in hard training

Feed	Sodium g/kg DM	Intake kg DM/day	Sodium g/day
Silage/Hay	1.5[1]	8[4]	12
Grain	0.3[1]	1.5[5]	0.45
Concentrate[6]	3.12	3	9.36
Minerals[2]	49	0.1	4.9
Total		12.6	26.7

[1] From Spörndly (2003)
[2] Krafft Miner blå pellets, 125 g salt/kg; 125*0,39 = 49
[3] Approximately 10 MJ/kg DM in silage (Spörndly, 2003)
[4] Minimum 1 kg DM/ 100 kg body weight and day.
[5] Oats 11.7 MJ/kg DM
6 Kraft Sport , energy content 12.0 MJ, Added 8 g salt/kg; 8*0.39 = 3.12 g Na/kg

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